REMARKS:

In response to the Official Action dated October 22, 2002, Applicants amend the application and request reconsideration. In the Amendment, claims 1, 3, 5, 8-10 and 12 have been amended. No new matter has been added. Claims 1-15 are now pending and under examination.

Applicants greatly appreciate that the Examiner has indicated that claims 3, 5, 8, 10-12, 14 and 15 would be allowable if they are rewritten to overcome the rejection under 35 U.S.C. §112, second paragraph, and that claim 13 would be allowable if it is rewritten to overcome the rejection under 35 U.S.C. §112, second paragraph, and to include all of the limitations of the base claim and any intervening claims.

Corrected drawings (Figures 20-25) are submitted in response to the requirement that corrected drawings be submitted.

Claims 1-14 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

Regarding the rejection on the ground that the language "optionally having a cage" renders the claims indefinite, although Applicants disagree, they have deleted the language from claims 1, 3 and 5 and the word "optionally" from claims 8-10 to expedite the prosecution of the application.

Applicants strongly disagree with the Examiner's statement that Applicants stated in the response to the Office Action of August 1, 2002 that the cage is the essence of the invention. Applicants have carefully reviewed the

response and have found no such statement. In fact, the specification, as well as the use of the word "optionally," make it abundantly clear that Applicants do not consider the cage as an essential element of the invention.

The Examiner rejected claims 1, 2, and 7 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al., rejected claim 4 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al. and further in view of Tanaka et al, rejected claim 6 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al. and further in view of Niizeki, and rejected claim 9 under 35 U.S.C. §103(a) as unpatentable over Niizeki in view of Yasui et al. and Masuda et al. For the following reasons, Applicant respectfully requests reconsideration and withdrawal of the rejections.

1. The presently claimed invention

The presently claimed invention relates to a rolling bearing which is used in a reduced pressure environment, such as in a vacuum pump apparatus, or in a high temperature environment, such as in heat rolling for fixing portions of business machines such as copying machines.

When lubricants for bearings are used under reduced pressure, solid lubricants are sometimes used to prevent contamination of the reduced pressure environment and the use of fluid lubricants such as lubricating oil has been increasing in order to improve the life and the reliability of the bearings. Fluoro-lubricating oil or fluoro-grease is used in a high temperature environment exceeding 200°C.

Although the fluoro-lubricants have high corrosion resistance and are less prone to evaporation under reduced pressure conditions; and are excellent in

heat resistance, less prone to evaporation, and chemically stable under high temperature conditions, they have higher specific gravity and poor wettability on the metal surface (the lubricating oil can penetrate into smaller gaps), in comparison with common mineral lubricating oil. Accordingly, formation of the lubricant membrane tends to be difficult, resulting in poorer lubricating conditions. Thus, to prevent the lubricating oil from contaminating the pump portion, a so called splashing lubrication system is usually used while the use of the oil bath lubrication with the fluoro-lubricating oil is restricted.

As mentioned above, the fluoro-lubricating oil which is only changed from a solid lubricant, cannot satisfy the requirements of (a) high load and high speed with a small size, (b) energy saving, (c) recycling and (d) long torque life.

In a high speed and high temperature environment, when fluoro-lubricating oil is used, the rise of the lubricating oil temperature is a serious problem to the prevention of contamination to the environment. Reduction in the thickness of the lubricating membrane is also a problem. How these problems relate to the contact angle is explained below.

In view of the above, in claim 1, the angular ball bearing has a contact angle between 10° and 45°, while the conventional angular ball bearing has a contact angle of 15°, 30°, 40° in order to support radial and thrust load at the same time.

If the contact angle is less than 10°, suitable for high speed rotation, the thrust load capacity is too small, and it can be more easily damaged by a fluctuating load. As a result, the load capacity of the bearing decreases so that longer bearing life with smaller size cannot be obtained. On the other hand, if

the contact angle exceeds 45°, although the thrust load capacity increases, spin sliding between the rolling surface of the rolling elements and the raceway surface of the rings increases, resulting in higher temperature between contact bodies. As a result, formation of an oil membrane becomes difficult and wear increases. For example, as described in connection with the fifth embodiment described in the present application, a vacuum pump apparatus is used at a temperature of 150°C, and is lubricated with the fluoro-lubricating oil "FOMBLIN OIL Y 25". Table 10 and Fig. 9 show the effectiveness of the contact angle range according to the present invention.

2. Wallin and Kinno et al.

2.1 Wallin

As described in the last response, Wallin discloses a bearing assembly for a dry-air-screw-compressor in which,

a first angular contact thrust ball bearing has a contact angle from 30° to 35°,

a second angular contact thrust ball bearing has a contact angle from 15° to 20°, and

the differences between the contact angles of the first and the second thrust bearings are about 10° to 20°, so that the internal force due to the centrifugal force becomes smaller and the induced axial force in the bearing system is minimized, in comparison with the rolling bearing having the same contact angle.

2.2 Kinno et al.

When a roller bearing, such as a taper roller bearing, is turned, its temperature is often greatly raised because of the friction between the end faces of the rollers and the inner surfaces of the flanges which are formed along the raceway.

In order to overcome these problems, the following method has been used in the art. The end portions of the rollers are designed as follows: the contact areas of the end faces of the rollers with the inner surfaces of the flanges are reduced to decrease the frictional area and to allow oil films to form at the contact regions, so that the temperature rise of the roller bearing due to friction is reduced.

However, as the contact areas are decreased, the surface pressure in the contact regions is increased. Hence, if the lubricant is insufficient, the metal parts at the contact regions are liable to directly contact with each other, and they may seize because of the heat generated by the contact.

In view of the above-mentioned difficulties, in Kinno et al., a surface layer of solid lubricant is formed on either the inner surface of the flange or the end faces of the rollers.

Further, in the case of the first example, the inner surfaces of the flanges 15 and 16 were subjected to phosphating, and then a polyamideimide DMF solution, in which PTFE particles were dispersed, was sprayed on the inner surfaces, to a thickness of 10μm, to form DMF solution layers. Finally, the polyamideimide resin on the inner race was thermally set at a temperature of 180°C, and the surface layers (PTFE) with solid lubricant were obtained.

Similarly, in the third example, the same surface layers were formed in the taper roller bearing.

3. The differences between claims 1 and 2 and Wallin and Kinno et al.

3.1 The presently claimed invention relates to a rolling bearing which uses as fluid lubricants lubricating oil and fluoro-grease containing a fluoro-containing polymer or is used in an atmosphere containing a gas comprising fluorides.

As described above, although the lubricants have high corrosion resistance and high heat resistance and are less prone to evaporation, they have higher specific gravity and poor wettability on the metal surface. Hence, it is necessary to solve the problems in forming a lubricant membrane for use in high temperature and high speed conditions with a small size.

In view of the problems, in the present invention, the lower limit of the contact angle is set to be 10°C, in order to achieve small size without a reduction in load capacity, while the upper limit of the contact angle is set at 45°C, in order to prevent undesirable formation of an oil film due to sliding and to prevent peeling wear from reducing bearing life.

3.2 As described in the last response, Wallin discloses an assembly for use in screw compressors for supporting rotors during high speed rotation, and has its object as minimizing the induced axial force in the bearing system due to the centrifugal force. However, Wallin does not teach or suggest the purpose of the present invention, and how to select the contact angle range in order to reduce peeling wear when fluid lubricants are used.

As we have pointed out in the last response, although the contact angle is known partially (see Table 2.12 shown in Reference 3 of the last response), the purpose of the presently claimed invention is to obtain miniaturization under conditions of fluid lubricants through selecting a suitable contact angle, and to obtain longer bearing life. Hence, it is necessary to consider the meaning of Wallin's disclosure from this viewpoint.

3.3 In Kinno et al., the solid lubricant layer is used because the contact areas are decreased and the surface pressure on the contact regions are increased so that they are liable to seizure if fluid lubricants are used.

Although the solid lubricant layer is effective in the contact areas specified in Kinno et al., it is necessary to change the bearing gap (clearance), the gap between rolling elements and cage pockets, when rolling surfaces and sliding surfaces change constantly.

However, it is complicated and expensive to form the surface layer of Kinno et al. On the other hand, if it is damaged due to wear, it cannot be supplied and repaired immediately like with fluid lubricants.

Namely, Kinno et al. does not teach the conditions of fluid lubricants according to the presently claimed invention.

In summary, Wallin does not disclose or suggest a combination of a fluoro-lubricant and the contact angle of ball bearing of the claimed invention. Further, Kinno et al. does not disclose the use of fluid lubricants. Therefore, the combination of Wallin and Kinno et al. does not teach the relation between fluid lubricant conditions and contact angle of the claimed invention.

In addition, in claim 9, the cage includes a PTFE, PPS resin material, and a through hole is formed in the bottom of the pocket.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #313MC/49472).

Respectfully submitted,

March 24, 2003

Herbert I. Cantor
Registration No. 24,392

CROWELL & MORING, LLP
P.O. Box 14300
Washington, DC 20044-4300
Telephone No.: (202) 624-2500
Facsimile No.: (202) 628-8844

HIC:SZ:tam